The Network Live Migration Design based on The Mobile IPv6 Network Mobility for Hybrid Cloud Network

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ABSTRACT

In the Cloud Computing, the migration mechanism can provide services, computing jobs and resources moved from a virtual environment to another virtual environment, and service providers can fit out their logic network architectures to offer services for user requirements. The network live migration across the different networks is a big challenge of the migration mechanism. In the paper, logical network architecture was proposed to provide the Cloud Computing in a hybrid network environment. The logical network concept, tunnel technology, domain name service and some existing network protocols were integrated into the proposed mechanism to provide network live migration across the different networks. The proposed mechanism implemented based on Open vSwitch and XEN. In our experimental results, we confirm that the proposed mechanism can provide network live migration across the different networks, and the network service will not be break. The performance evaluations also show that the proposed architecture can better than the NEMO solution.

Keywords -**Virtualization, Virtual Network, Migration, Network Migration, Cloud Computing, Network Mobility.**

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1. INTRODUCTION

In the past few years, Cloud Computing proposed in [1] is a very hot topic of network service, and the users can provide many kinds of network services on a ubiquitous, convenient, and on-demand network environment. The virtualization is a software technology to simulate the operation of the hardware platform, operating system, storage device, or network resources, and is a key technology to support Cloud Computing. In [2], the authors investigated the adoption of Cloud Computing based small andmedium scales enterprises in Northwestern Nigeria.

Based on the network virtualization, the IaaS (Infrastructure as a Service) providers could allocate network resources from the resource pool, and configure network environment to offer services for the user requirements. However, the IaaS providers may need to move these services, computing jobs or resources from a virtual environment to another virtual environment according due to some reasons. The computer center may need to close the servers due to the power outage, and the services, computing jobs or resources deployed on the computer center should be migrated to another computer center. For example, many Canadians cannot use their Visa cards for much of the day due to a data center power outage. Facebook was down for several hours in January 2013, Yahoo Mail cannot provide service in December 2013. Amazon S3 Service Disruption in [3], and Facebook, Instagram & WhatsApp global shutdown in [4].

The migration mechanism was proposed to move the services and resources between two virtual environments. The migration mechanism can be divided into two issues. The first issue is to select the target machine, and the second issue is to migrate the virtual machine, services or resource from the migrated machine to the target machine. The first issue is the cloud resource assignment problem, and the second issue is the technology to move the virtual machine, services or resource.

In the paper, the proposed migration mechanism based on the Network Mobility (NEMO) [5] can provide network live migration that can move a set of VMs and resources, which are deployed on a set of real machines, to another set of real machines. In the proposed mechanism, the network configuration in the old set of real machines will be set into the new set of real machines, and the services will not be blocked. The cloud resource management problem in the proposed mechanism is very differ to the researches in the [6]-[10], and some decision polices was proposed in the target machine decision procedure in order to provide better service quality after the network migration. In the proposed solution, the target machine decision procedure will generate the migrated host and resource list, and the network migration procedure will migrate the host and resource according the list. Moreover, in the proposed solution, a heretical NEMO architecture was introduced to provide network live migration in the hybrid cloud network environment. Some shell scripts and some network protocols are integrated into our mechanism to provide seamless network live migration in the hybrid cloud network environment.

The remainder of this paper is organized as follows. The problem statement and related works were in the section II.

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The network architecture is described and proposed approach were described in Section III. The target machine decision polices were listed in the Section IV. Section V presents the performance evaluation for the proposed system, and conclusions and suggestions for future directions are given in Section VI.

2. RELATED WORK

The migration mechanism is used to move the services and resources between two virtual environments. The migration mechanism can be divided into the cloud resource assignment problem and the migration technology. The cloud resource assignment problem and the migration technology is to select a target machine or a set of target machines to migrate. The migration technology is to move the virtual machine of resource from the original machines to the target machines.

There are a lot of researches proposed to solve the cloud resource assignment problem. The cloud resource assignment problem is an important issue that is used to deploy the resource or service into the cloud network [6]-[10]. In these papers [6]-[10], some decision polices was proposed to select the target machine in order to deployed the services or virtual machine with low cost. However, most of these researches are focused on finding the target machines from the cloud, and assigning the jobs, resources, or virtual machines to these machines. In the network migration problem, a set of machines should be selected from the cloud and the set of jobs, resources, or virtual machines on the original machines should be move to the set of target machines. The network environments on the target machines should be the same as that on the original machines. The Controller Placement Problem inSDN was studied and survey in [11].

The migration mechanisms can be categorized into off-line migration and live migration. The off-line migration mechanisms will block the services during the migration and the live migration mechanisms can still provide service during the migration. It means that, after migration, the IP address of the migrated service or host cannot change.

Moreover, these migration mechanisms also can be classified into host migration, resource migration and network migration according to the migration service scale. The host migration is to move the services and resources between the virtual or real machine and most of the migration mechanisms [12]-[15] support the live host migration. VMware [15] can provide resource migration that can move a set of resources from a virtual environment to another virtual environment.

The network migration [16]-[20] is used to move a set of VMs and resources which are deployed on a set of real machines to another set and the target network can be reconfigured according to the original network configuration. The network live migration across the different networks is a big challenge that the routing path, QoS policy, and network topology will be changed when the set of VMs and resources were moved from one subnet to another subnet. Moreover, the network service is based on the TCP/IP stack. When a set of VMs and resources move to another subnet, the IP addresses of these VMs and resources should be changed, and the service provided by these VMs and resources should be block. So, in order to provide non-stop network service during the network migration, the basic idea is to assign the private IP addresses to these VMs and resources, and the IP addresses will not need to change after network live migration. But this solution cannot provide the network live migration in the public network.

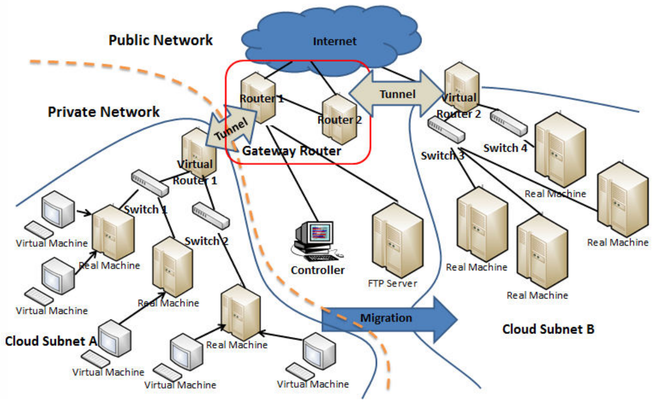

Fig. 1. The Proposed Architecture.

3. NETWORK ARCHITECTURE

The network type and security level of Cloud computing can be categorized into public clouds, private clouds, and hybrids clouds. It has a great effect upon the design of network migration. For private clouds, that are designed on the private network, and the resource are only accessible by a single point providing well control and privacy functions. Thus, after completing a network migration, the provider can update the setup information stored in the single point, and the end-to-end service stills can access. The public clouds and hybrid clouds are designed on the public network, it is a challenge that how to provide service after network migration. It because that the IP addresses of the migrated service or hosts cannot change in orders to provide live migration. However, when the service or hosts migrated to different subnet, the IP addresses of the migrated service or hosts will need to change.

In the paper, a logical network structure is proposed as showing the Fig. 1. The gateway routes are a set of virtual routers, which are used to forward the packets between public networks and cloud networks. The cloud subnets could be at public network or private network. Each virtual router in the gateway routes would be assign one public IP address and at least one logic IP address. The public IP address is used to provide network access from the public network, and the logic network address is used to create a tunnel with another router in the cloud subnet. The logic IP address can be a public IP address that can be accessed from Internet or be a private IP address. Therefore, based on the gateway routes and tunnel technology, a logical network structure can be organized on the public network environment.

The controller is used to setup the routing policies and routing paths in the gateway routes, and to perform the migration procedures to provide the network migration, resource migration and host migration. The DNS server

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keeps the relation between the IP address and hostname. The FTP server deployed in public or private network is used to store the migration data and image files that are uploaded from the migrated host and can be downloaded by the target host.

In the proposed architecture, several hosts can be organized into a cloud subnet, and one of the hosts would be set as a subnet router. The subnet router could establish a tunnel with one of the gateway routes or another subnet router. When a subnet wants to join the cloud network, the controller could allocate a range of IP address to the subnet, select one router from the gateway routes based on the selection policy, such as the loading balance, QoS requirement, or host performance, and establish a tunnel with the joined subnet router. The allocated IP addresses would be logic address, and can be used to organize a logical network on the hybrid network environment. The controller would add the relation of IP subnet/address and domain/hostname name into the DNS server.

Moreover, there are several Racks would be setup in a container data center, and more than ten Blade servers would be installed in each Rack. How to organize the network for these servers is another challenge. Based on the proposed architecture, several Blade servers could be organized into a cloud subnet, and one of the servers would be set as a subnet router as showing the Fig. 2. In a container data center, these Blade servers can be divided in to several cloud subnets, and one of the servers can be set as a border router to create a connection between the gateway routes and these cloud subnets.

The Open vSwitch and XEN are installed in these real machines. The Open vSwitch was introduced to provide switch services for the VMs between a set of real machines. The DNS server and DHCP server are hosted on the software router. The DNS server will keep the relation between the IP and hostname, and the DHCP server can be used to provide the automatic host deployment mechanism proposed in [9] and name service for internet service access. FTP was introduced to transfer the VMs' files and a FTP server is used to store the VMs' files.

The Network Mobility (NEMO) technology is proposed to provide Mobile Networks to attach to different points in the Internet. In order to use the NEMO technology to provide network live migration, the subnet router can be set as mobile router (MR) , and the gateway routes is set as the home agent of the mobile router (MR_HA). The allocated a range of IP address can be solved by Mobile Network Prefix, and the mobile router would assign a home address with the Mobile Network Prefix to each host in the cloud subnet.

The Binding Update is used to update the relation of MR's Care-of Address and MR's home address. According to the MIPv6 defineition, the packets will be forward to the MR's Care-of Address. Thus, the Binding Update procedure can be used to updated the tunnel for the topology change after network migration.

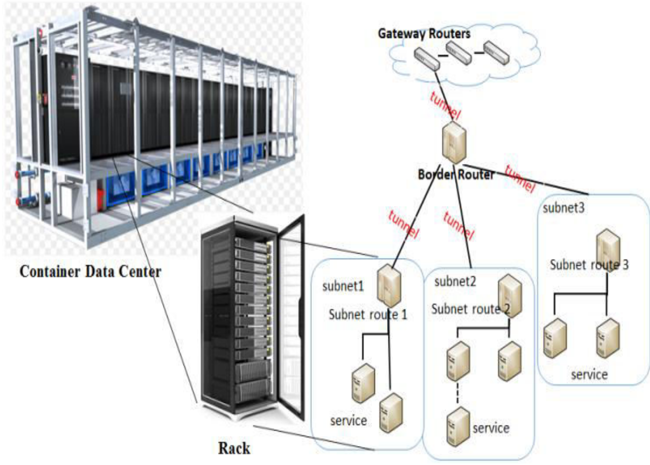

Fig. 2. Logic Network Architecture of a Container Data Center

4. MIGRATE PROCEDURE

In our proposed architecture, the controller performs the migration procedures to move the virtual machines and resources deployed in a cloud subnet to a target cloud subnet. The migration procedures can be divided into three steps as the following and shown in the Fig. 3:

1. Resource information collection: In the first, the list of migrated hosts or subnet should be sent to the controller, and then, the controller will call the scripts to collect the information of migrated VMs and resources, such as CPU utilization, memory/storage utilization, bandwidth requirement, and so on. Moreover, the network configuration information will also be collected.

2. Target machine decision: In the second procedure, the controller will find several candidate subnets that can be set as target subnet. The total resources of candidate subnet should be larger than or equal to the resource requirement of the migrated subnet. Then, the procedure will select the target subnet from the candidate subnets, select the target machine for each migrated VM and resource, and arrange the migration order of each migrated VM and resource.

3. Network migration: In the procedure, the controller will perform the scripts to back up the migrated VMs and resources, to upload the backup file to the FTP server, and to download the backup file to the target machine. After migration, the network configure procedure will be performed to update the network environment.

The detail migration procedures are shown in the following sections.

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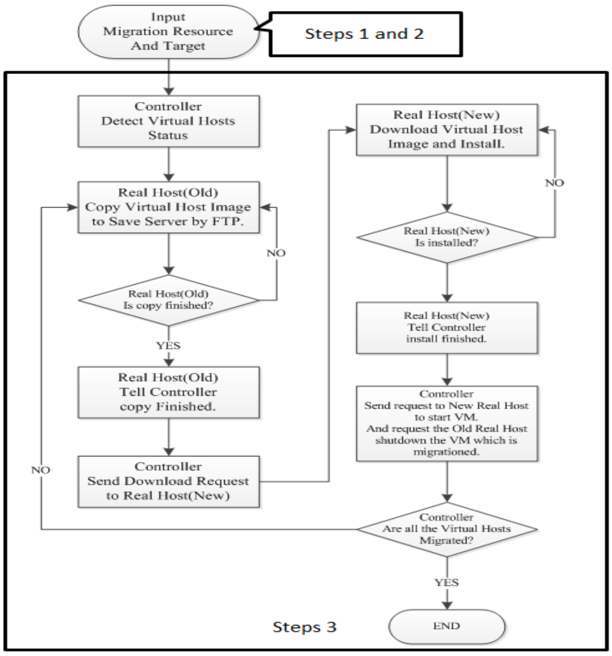

Fig. 3. The Migration Flow Chart.

4.1 Resource Information Collection

When the manager submits a list of the migrated hosts or subnet, the controller needs to run some scripts to collect the resource requirement of the migrated machine, and to get the network configuration information. The network configuration information will be stored in the controller, and the resource requirement of the migrated machine will be used in target machine decision procedure.

4.2Target Machine Decision

The target machine decision can divide in to two steps. The first step is to find the best target subnet from the candidate subnets, and the second step is to decide the target machine for each migrated machine. Let N denotes the set of the migrated VMs, M denotes the set of the candidate subnets, and m is a candidate subnet selected from M.

There are kinds of type of resources, which are providing in the virtual machine. CPU, Memory, network bandwidth, local and remote disk are mostly common resources used in the cloud computing. S is the set of resources, and s^i is one kind of resources. Let, vm_j is the virtual machine j in N, s_{vmj}^i is the required amount of resource s^i in vm_j, and k is the amount of resources. REQ(vm_j) is a vector to denote the resource requirement of vm_j, and can be shown as follow:

$$REQ(vm_j) = [s_{vmj}^1, s_{vmj}^2, \cdots, s_{vmj}^k] \quad (1)$$

Let n is the amount of virtual machine of N, REQ(N) is a n*k matrix to denote the resource requirement of N, and can be shown as follow:

$$REQ(N) = \begin{bmatrix} REQ(vm_1) \\ REQ(vm_2) \\ \vdots \\ REQ(vm_n) \end{bmatrix} \quad (2)$$

$MAX_{si}(N)$ and MIN $_{si}(N)$ are the maximal required and minimal required of resource s^i respectively and $Total_{si}(N)$ denotes the total required amount of resource s^i. These notations can be list as follow:

$$MAX_{si}\ (N) = max\{s_{vmj}^i\} \quad \forall vmj \in N \quad (3)$$

$$MIN_{si}\ (N) = min\{s_{vmj}^i\} \quad \forall vmj \in N \quad (4)$$

$$Total_{si}\ (N) = \sum_{\forall vmj \in N} s_{vmj}^i \quad (5)$$

$m_i$is an real machine i, and CAP(m_i) is a vector to denote the capacity of real machine m_i and can be shown as follow:

$$CAP(m_i) = [s_{mi}^1, s_{mi}^2, \cdots, s_{mi}^k] \quad (6)$$

Let p is the amount of virtual machine of m, CAP(m) is a p*k matrix to denote the resource requirement of m, where p is the amount of machine of m, and can be shown as follow:

$$CAP(m) = \begin{bmatrix} CAP(m_1) \\ CAP(m_2) \\ \vdots \\ CAP(m_p) \end{bmatrix} \quad \forall m_p \in m \quad (7)$$

$MAX\_cap_{si}(m)$ and $MIN\_cap_{si}(m)$ are the maximal amount and minimal amount of resource s^i in m respectively, and $Total\_cap_{si}(m)$ denotes the total amount of resource s^i. These notations can be list as follow:

$$MAX\_cap_{si}(m) = max\{s_{mj}^i\} \quad \forall mj \in m \quad (8)$$

$$MIN\_cap_{si}(m) = min\{s_{mj}^i\} \quad \forall mj \in m \quad (9)$$

$$Total\_cap_{si}(m) = \sum_{\forall mj \in m} s_{mj}^i \quad (10)$$

All the elements in candidate subnets M should satisfy the following conditions:

$$MAX\_cap_{si}(m) \geq MAX_{si}(N) \quad (11)$$

$$MIN\_cap_{si}(m) \geq MIN_{si}(N) \quad (12)$$

$$Total\_cap_{si}(m) \geq Total_{si}(N) \quad \forall m \in M \quad (13)$$

$Cost_{si}^N(m)$ is the cost function to denote the cost when the cloud allocates the required resource s_i of N from the subset m, and $Cost^N(m)$ is the total cost when the system allocates the required resource of N from the subset m.

SEL(M) is the selection function to select the best target subset, m’, with the minimal cost from the candidate subnets M.

$$m' = SEL(M) = min\{Cost^N(m)\} \quad \forall m \in M \quad (14)$$

The second step is to decide the target machine for each migrated machine. Let L denotes the migration order list, and NL is the set of the VM in L. The records in L is denoted as (vm_j,m_i), which means that move vm_jin the migrated subnet Nto real machine m_i in m. Choice(m) is a selection function that will select a real machine m_i from m. More than one VM can be hosted on a real machine, and VM(m_i) denotes the set of VM hosted on real machine m_i. In the proposed mechanism, the migration order is decided based on the following algorithm:

1. Selects vm_j, and $vm_j \in \{N\} - \{N_L\}$
2. m_i = Choice(m), and $\mathrm{CAP}(m_i) \geq \in REQ(vm_j) + \sum_{vm_k \in \mathrm{VM}(m_i)} REQ(vm_k)$·
3. Inserts (vm_j,m_i) into L.
4. If $\{N\} \neq \{N_L\}$, return step 3. Else, the L is the final migration order.

4.3Network Migration

The migration order will be generated in the previous step, and the controller server will perform the script codes according the migration order. The network migration procedure can be divided into 5 steps.

Step 1: Upload virtual machine file

In the step, the migrated host needs to upload the image file to the FTP server. The following commands are an example to upload the image file.

```
str="\"{/etc/xen/$VM.cfg,/mnt/storage/$VM.img}\""
echo "Upload $VM"
echo "`$ssh_str@$S_IP curl -T $str --user root:$passwd ftp://$TEMP_IP`"
```

Step 2: Modify virtual machine network configurations

In the step, the network environment of the image file will be modified using the following commands.

```
mount -o loop /root/$VM.img /mnt
sed -i "s/$IP/$newIP/g" /mnt/etc/sysconfig/network-scripts/ifcfg-eth0
sed -i "s/$GW/$newGW/g" /mnt/etc/sysconfig/network-scripts/ifcfg-eth0
umount /mnt
```

Step 3: Download virtual machine file

In the step, the target machine can use the following commands to download the image file from the FTP server.

```
echo "Download $VM"
echo "`$ssh_str@$D_IP curl -o /etc/xen/$VM.cfg -u root:$passwd ftp://$TEMP_IP/$VM.cfg`"
echo "`$ssh_str@$D_IP curl -o /mnt/storage/$VM.img -u root:$passwd ftp://$TEMP_IP/$VM.img`"
```

Step 4: Virtual machine switch

In the step, the following commands can be used to shut down the original virtual machine, and to startup new virtual machine.

```
echo "`$ssh_str@$D_IP xm create /etc/xen/$VM.cfg`"
echo "`$ssh_str@$S_IP xm destroy $VM`"
echo "$VM Started..."
```

Step 5: Tunnel updated

In the step, the following commands can remove the old tunnel that provide the forwarding path between the gateway router and the migrated subnet, and create a new tunnel between gateway router and the target subnet.

```
route del -net 192.168.1.0 netmask 255.255.255.0 dev eth0
route add -net 192.168.1.101 netmask 255.255.255.255 dev tun2
route add -net 192.168.1.102 netmask 255.255.255.255 dev tun0
route add -net 192.168.1.103 netmask 255.255.255.255 dev tun2
```

4.4 Target Machine Decision Polices

There are two decision functions in the target machine decision. The first decision function is to select the best target subnet from the candidate subnets, and the second one is to decide the target machine for each migrated machine.

The target subnet decision function, SEL(M), is used to select the best target subnet from the candidate subnets based on the cost function, CostN(m). Most of the related works [5]-[9] are focus on how to select the best target machine from the candidate subnets, and target subnet decision function in the paper is to select the best target subnet based on the equation (14).

The migration order decision function, Choice(m) is to decide the target machine for each migrated machine. Three decision politics were considered in the paper, and explained in the following.

5. PERFORMANCE EVALUATIONS

The major objective of the proposed mechanism is to provide the network migration using existing network protocols. As shown in the Fig. 4, a hybrid cloud network was built up in our campus network. Four subnets are at three buildings. In subnet 1, one host is used to provide router service, and two hosts (hosts 1 and 2) can provide several virtual machines and services. The controller and DNS server are installed at the same host, and the FTP server is at the different host.

In subnets 2 and 3, each subnet has one host used to provide router service, and one host can provide several virtual machines and HTTP services. The subnet1 is at the private network, and the subnets 2 and 3 are at the public network. The CN is used to test the service connectivity during the network migration. The ping packets will be sent from the CN to the target VM, and the turn a rout time of ping can be used to measure the service break time during the network migration. The router 4 and host 5 are used to create a tunnel with one of three subnets and host 5 can join one of the subnets.

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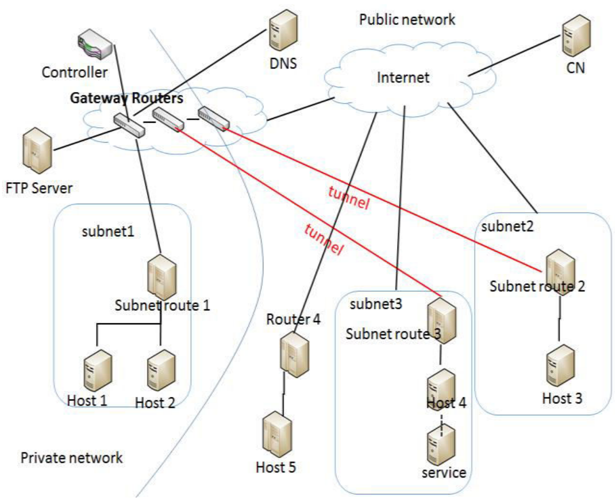

Fig. 4. The Experiment Environment.

We implemented the proposed solution and NEMO solution to evaluate the performance to compare the differences between the proposed solution and NEMO solution. In order to support NEMO solution, the open source implementation of UMIP [21] was installed in the evaluation environment, and mip6d and radvd were setup to provide the NEMO service.

There are three scenarios in the experiments. In the scenario 1, the VMs at subnet 2 will be migrated to subnet 1, and the experiment results of proposed solution were shown in the Fig. 5, and the results of NEMO solution were shown in the Fig. 6. In these figures, the vertical line is the turn a rout time of ping and the horizontal line is experiment elapsed time.

As shown in the Fig. 5, when the image file of vm1, vm2 and vm3 were uploaded to the FTP server, the turn a rout time is increased to 100ms. It because that these image files are transferred from the hosts at subnet 2 to the FTP server at subnet 1, and the ping packets are sent from CN to gateway router and forwarded to the subnet 2. The tunnel between the gateway and subnet 2 is very busy. In the download period, these image files were sent from the FTP server to the host 1 and host2, and will not affect the turn a rout time. When the image files were at the target machines, the target machines will start up according to the image files. Then, the gateway router will delete the old tunnel and create a new tunnel with the new subnet 2. The turn a rout time is increased due to the tunnel changed. In the NEMO solution, the service break time is due to the binding update procedure. That berceuses that the MR should sent the binding update request to MR_HA to update the binding cache. In the Fig. 6, the MR of subnet 1 and the MR_HA are at the same domain, and the service break time is very short.

In the scenario 2, the VMs at subnet 2 will be migrated to subnet 3 and the experiment results were shown in the Fig. 7, and the results of NEMO solution were shown in the Fig. 8. The turn a rout time of the download period is larger than that of scenario 1. It because that the download packets sent from FTP server to subnet 3 through the gateway router. The traffic load at gateway was increased. The turn a rout time is also increased due to the tunnel changed. These scenarios can show that the proposed mechanism can provide network migration at hybrid network environment. In the Fig. 8, the service break time is large than 1 min. It berceuses that the MR of subnet 3 and the MR_HA are at the different domain, and there is no tunnel between these two subnets. Thus, the binding update request should be sent to the gateway router and forward to the gateway of MR_HA, and the delay of binding update procedure is increased.

In the scenario 3, a host, RH5, at public network joins the subnet 2 through the tunnel, and provides some network services. The VMs at subnet 2 will be migrated to subnet 3, but the VMs at RH5 will not need to migrate. In the scenario, the tunnel between RH5 and subnet 2 will be deleted and create a new tunnel between RH5 and subnet 3. The NEMO solution cannot solve the scenario 3. The experiment results were shown in the Fig. 9. When the vms 1, 2 and 3 were uploaded their image file, this had a great effect upon the turn a rout time of vm 4. It because that the image file is transferred from the host at subnet 2 to the FTP server at subnet 1, and the ping packet is sent from CN to gateway router and forwarded to the RH5 through the subnet 2. The turn a rout time is also increased due to the tunnel changed. The scenario shows that the proposed mechanism can provide logical network reconstruct during the network migration at hybrid network environment. Moreover, from the service break time in Fig. 8, the NEMO solution cannot provide well network live migration.

6. CONCLUSIONS

The migration mechanism was proposed to provide services, computing jobs and resources moved from a virtual environment to another virtual environment. The network live migration across the different networks is a big challenge and the solution was proposed in the paper. In the proposed solution, some shell scripts and existing network protocols were integrated with Open vSwitch and XEN in order to provide the network migration mechanism which can move a set of services and resources from a set of virtual/real machines to another set of virtual/real machines and reconfigure the network configuration automatically based on the migrated network environment.

The performance evaluations show that the proposed mechanism can move the set of services and resources between different set of virtual/real machines across the router, and the service will not be break.We test our proposed solution in our campus. The solution proposed in [16] is a prototype and evaluated it in a small environment. Moreover, the performance evaluations also show that the proposed architecture can better than the NEMO solution.

In the future, the target machine decision will be improved in order to provide better migration, and more network services will be used in the experiment to show the performance of the proposed network architecture.

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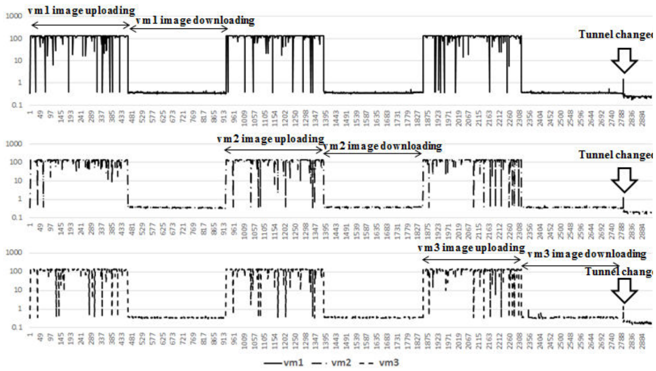

Fig. 5. The Experiment Results of Proposed Architecture of Scenario 1.

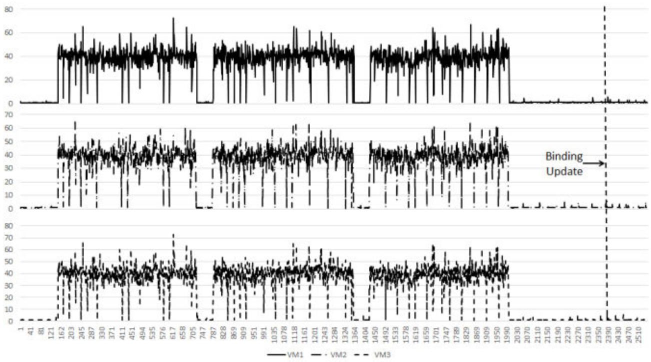

Fig. 6. The Experiment Results of NEMO of Scenario 1.

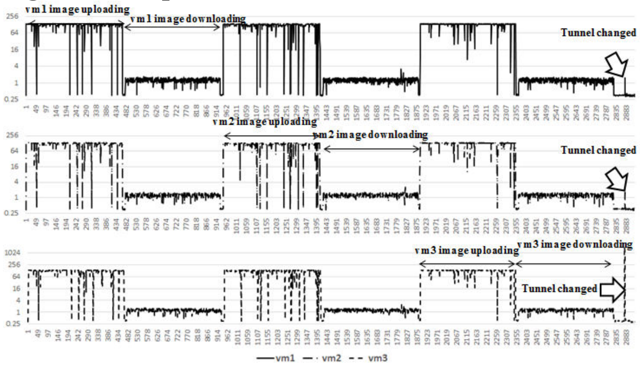

Fig. 7. The Experiment Results of Proposed Architecture of Scenario 2.

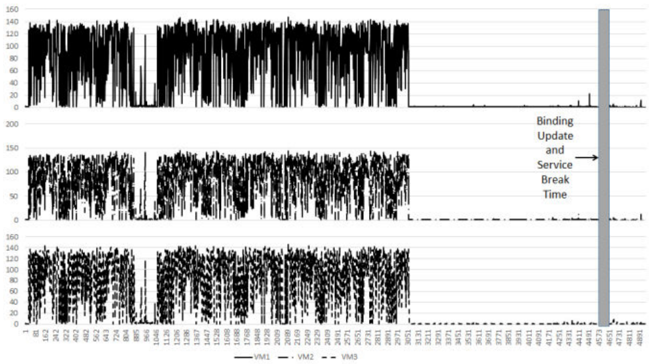

Fig. 8. The Experiment Results of NEMO of Scenario 2.

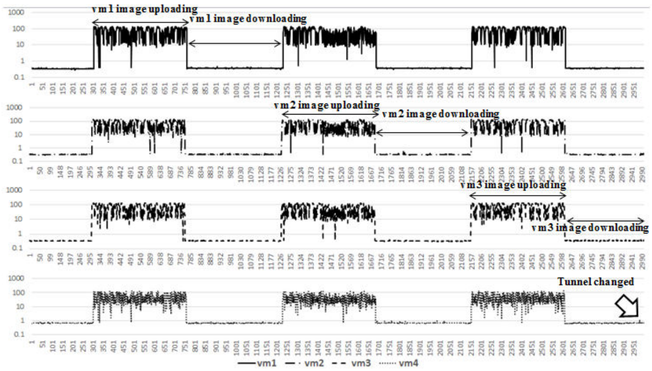

Fig. 9 The Experiment Results of Propose